## PYROXENE WHISKERS IN CP INTERPLANETARY DUST PARTICLES: EVIDENCE OF VAPOR PHASE GROWTH

J.P. Bradley and D.E. Brownlee, *Dept. of Astronomy, Univ. of Washington, Seattle, WA 98195*
D.R. Veblen, *Dept. of Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 02138*

CP micrometeorites are highly porous and fragile interplanetary dust particles (IDP's) that have chondritic elemental abundances. Among the mineral species found within these particles are pure enstatite crystals, which are unique among the micron-sized constituents of CP IDP's in that they are euhedral. They exhibit at least three distinct forms, henceforth referred to as rods, ribbons and platelets, whose morphologies are totally inconsistent with those of rock-forming pyroxenes that have crystallized from a melt.

Chemical and structural features of the pyroxenes were investigated by analytical scanning and transmission electron microscopy. Rods consist of single crystals that are grossly elongated along the crystallographic [100] direction. Ribbons are blade-shaped crystals that are morphologically similar to rock-forming pyroxenes (Fraundorf, 1981) except that they are also elongated along [100]. Platelets consist of very thin (200-500 Å) angular crystals whose habits lie in a-c projection (i.e. they are thin parallel to [010]).

Each of the three morphological forms were found to possess characteristic crystallographic defects. For example, some of the rods contain axial screw dislocations that run parallel to the lengths of the crystals. High-resolution images and diffraction data indicate that they consist exclusively of clinoenstatite containing isolated [100] stacking defects. Ribbons also consist exclusively of clinoenstatite that contains isolated [100] stacking defects. Platelets consist of pervasively intergrown ortho and clinoenstatite, together with extreme stacking disorder.

The presence of whiskers and platelets in CP micrometeorites has important implications with respect to the origin of CP IDP's. Both synthetic and naturally occurring whiskers of a variety of compositions have been observed (Blakely and Jackson, 1962; Veblen and Post, 1982): apart from their distinctive morphologies, a characteristic feature of those grown by direct vapor-to-solid condensation is a rod-like morphology containing an axial screw dislocation (Blakely and Jackson, 1962). Donn and Sears (1963) have pointed out that nucleii present in the solar nebula are likely to have lead to whiskers and platelets containing screw dislocations. Such defects would have allowed equilibration of the saturated vapor phase with a stable crystal phase at saturations well below those required for other models of condensation.

Our observations provide strong evidence that primary condensates from either the solar nebula or pre-solar environments have been preserved in certain IDP's and that they can be identified and studied by electron-beam methods. Analyses of these particles should provide fundamental insights into the kinetic aspects of condensation. One intriguing aspect of this effort is the observation that growth of rods by axial screw dislocation appears to be confined to enstatite.

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Donn, B. and G.W. Sears, 1963. *Science* **140**, 1208-1211.
Fraundorf, P., 1981. *Lunar Planet. Sci. 12th*, 291-293.
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## $SiO_2$-RICH CHONDRULES IN ORDINARY CHONDRITES

Cheryl Brigham, M.T. Murrell and D.S. Burnett, *Division of Geological and Planetary Sciences, Caltech, Pasadena, CA 91125*

The solar system abundances of Mg, Fe, and Si dictate that chondritic meteorites are silica-deficient compared to most terrestrial or lunar igneous rocks; thus olivine-orthopyroxene assemblages are commonly observed in ordinary chondrites. However, in the unequilibrated H-chondrites Sharps, Bremervörde, and Dhajala, we have observed chondrules and fragments which contain either tridymite or cristobalite as a major phase. Coexisting with the $SiO_2$ is predominantly low Ca pyroxene, as expected for a well-crystlalized, silica-saturated chondrule. These chondrules are striking in being conspicuously depleted in Ca and Al-rich phases: no feldspar was observed and only tiny grains of Ca-rich pyroxene and material of apparently glass composition have been found. To date, we have observed approximately 20 of these chondrules/fragments; their abundance is $\geq 3/cm^2$ of section. A typical object from each of the three meteorites is described below.

The Bremervörde chondrule (spherical, 0.3 mm radius) is about 40% $SiO_2$ (by area) with the $SiO_2$ concentrated towards one side, except for a few laths in the center and a discontinuous inner rim of $SiO_2$ grains around the pyroxene part of the chondrule. Some grains appear to be crystals which nucleated on the rim and grew inward. The chondrule is completely surrounded by an outer pyroxene rim. The interior pyroxene varies in composition, roughly radially, from $En_{66}Wo_{0.4}$ to $En_{85}Wo_{0.1}$. In the center of the chondrule is a very small region of glass and clinopyroxene. The U content of the $SiO_2$ phase is 33 ppb.

The Dhajala chondrule (spherical, 0.4 mm radius) is approximately 86% pyroxene, 8% $SiO_2$ phase and 6% metal. The $SiO_2$ occurs as angular laths, thin concentric arcs or lamaellae oriented parallel to linear chains of metal blebs. Some pyroxene regions show a lamaellar (exsolution?) texture. Two analyses give $En_{74}Wo_2$ and $En_{36}Wo_{19}$. The upper limit for the U content of the $SiO_2$ is $\leq 8$ ppb.

The Sharps chondrule/fragment (half-circle, 0.6 mm radius) has small (~ 10 micron) $SiO_2$ grains (~ 43%, volume) surrounded by interstitial layers of essentially pure fayalite. This fragment was completely rimmed by fine-grained olivine after being broken. Pyroxene in this object is somewhat more Mg-rich ($En_{88}Wo_{0.2}$) than that in other $SiO_2$-bearing chondrules and appears uniform in FeO content.

The bulk composition of these chondrules is probably similar to some reported by McSween (1977) from unequilibrated ordinary chondrites and Kakangari, except that ours are more deficient in CaO and $Al_2O_3$. Presumably, the $SiO_2$-rich phase in the chondrules of McSween is typical chondrule glass; ours generally is crystalline.

A simple explanation for the $SiO_2$-rich, low Ca, Al chondrules found in Bremervörde and Dhajala is a process involving fractional condensation of a nebular gas. If the high temperature fraction ($\geq$ 1350°K) is removed after condensation, there is excess $SiO_2$ left in the gas which can condense as $SiO_2$. The $SiO_2$-rich chondrules from Sharps are clearly different from those observed in Bremervörde and Dhajala. The texture of the Sharps objects is suggestive of alteration or decomposition. The fayalite-$SiO_2$ assemblages observed in Sharps could be explained by rapid quenching of the immiscible liquids formed in the two liquid regions of the FeO-MgO-$SiO_2$ system. One of these liquids would yield Mg-rich pyroxene and $SiO_2$; the other would produce ferrosilite and $SiO_2$ which would decompose to form fayalite and $SiO_2$.

McSween, H.Y., 1977. *Geochimica-Cosmochim. Acta* **41**, 1843-1860.

## ON THE USE OF IRON BY THE ESKIMOS OF GREENLAND

V.F. Buchwald, *Dept. of Metallurgy, Build. 204, DTH, 2800 Lyngby, Denmark*

In the large archaeological material which has been collected upon Greenland and which is now in the National Museum, Copenhagen, there are a few implements that, surprisingly, have been fabricated from iron or have cutting edges of iron. A systematic examination of 70 arrowheads, ulos (woman-knife) and similar samples reveals that it is possible — in spite of a general very poor state of conservation — with modern methods, such as metallography and electronmicroprobe analysis, to determine the composition and origin of the specimens.

One part is meteoritic iron with 7,5-8,5% Ni. It is slightly to heavily coldworked and has attained hardnesses of 275-350 HV. Some samples may have been ground or polished to final shape, but forging or heat treatment has not been applied. The origin is probably the Cape York iron meteorite, a group IIIA medium octahedrite.

Another part is native iron with 1-4% Ni. It is ferritic with cementite inclusions, and is coldworked to 180-230 HV. The original pea-sized native iron minerals of Disko Island have lower hardnesses, 130-160 HV.

The third part of the old tools contains wrought iron made in Denmark and Norway in the medieval ages; it is speculated that the Eskimos acquired it by trading with the Norsemen, 1000-1400 A.D., and in a later period by excavating the abandoned farms of the Norsemen.

The Eskimos are thus unique in having utilized three different types of iron for their tools.